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Name of Principal Author and all other author(s): LTC Jeffery Schamburg, John Ruck, Mr Leroy Jackson

Principal Author's Organization and address:
TRAC-Monterey
700 Dyer Road Annex/Building 246
Monterey, CA 93943

Phone:(831) 656-3086

Fax: (831) 656-3084

Email: jeffrey-schamburg@us.army.mil

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Logistics Battle Command

Briefing for MORS 75th Annual Symposium

Jack Jackson (TRAC-Monterey)

and John Ruck (R&A)

14 June 2007

Purpose & Agenda

- **Purpose: To describe TRAC-MTRY research in support of TRAC Sustainment Battle Command modeling and analysis.**

- **Agenda:**
  - **LBC Overview.**
  - **Past: Maintenance Sustainment & LBC so far.**
  - **Present: LBC status & schedule.**
  - **Future: LBC4EAB & HPCC and DOE.**
  - **The Team.**
  - **Functional Requirements.**
  - **Common Operating Picture.**
  - **Distribution Network.**
  - **Forecasting.**
  - **Battle Command.**
  - **Prototype & Stand-alone Demonstration.**

Logistics Battle Command

Project Description: The LBC model will be developed with and for TRAC- LEE. LBC has planning and decision support features to enable a simulated logistics battle captain to (1) monitor the logistics common operating picture, (2) forecast demand for most classes of supply, and (3) initiate and adjust missions to distribute supplies and perform sustainment functions. LBC integrates with COMBAT XXI to represent sustainment operations at brigade and below.

Technical Approach: Capitalize on capabilities developed with TRAC-LEE and TRAC-WSMR during the Dynamic Sustainment modeling effort to develop a model that uses OPTEMPO and demand data and represents sustainment results.

Sponsor: Logistics FACT & TRAC

Partners: TRAC-LEE, TRAC-WSMR, & CASCOM

LBC will support analysis of future force sustainment battle command.

Key Features:

- Development began in late FY06 and the initial capability is projected for December 2007.
- LBC represents the common operating picture and running logistics estimates.
- LBC represents the distribution network including nodes (storage, maintenance, supply, medical, and field services) and arcs (modes of transport).
- LBC represents the sustainment plan as a task network and supports monitoring and adjusting sustainment execution.
- Future Echelons Above Brigade (EAB) research focuses on a stand-alone tool to emulate future decision support capabilities, forecasts bulk consumption, represents bulk shipments, and accounts for non-recurring demand items.

Legacy Capability: Dynamic Sustainment

- **Stand-alone maintenance model.**
  - **Develops availability curves.**
  - **Develops reliability failures (MTBSA).**
  - **Produces maintenance queues, MMH requirements and MMH performed.**
  - **Models time to travel between repair resources and disabled vehicles.**
  - **Allows combat damage to repair assets.**

- **Integrated COMBT XXI maintenance module.**
  - **Replaces random draws with COMBAT XXI OPTEMPO to produce reliability failures, then sends the failure to COMBAT XXI.**
  - **Receives COMBAT XXI combat damage to calculate repair requirements and availability.**
  - **Return To Duty for failed systems (combat damage and reliability) is accomplished by the module and passed to COMBAT XXI.**

- **Current status.**
  - **Stand alone model is complete and in use for studies.**
    - **Joint Light Tactical Vehicle (JLTV) Evaluation of Alternatives (EOA).**
    - **Future COMBAT System (FCS) Fiscal Year 2007 OSD Update.**
  - **Integrated module is currently being tested and refined as TRAC-LEE develops COMBAT XXI sustainment behaviors.**

LBC Development History

- **Requirements Analysis Document (6 Sep 06).**
  - Describes data requirements, algorithms and knowledge to represent logistical operations, logistical forecasting, and the distribution network for echelons above brigade with a focus on forecasting and distribution management.

- **Preliminary Design (17 Nov 06).**
  - An object oriented representation of classes (data and methods), class relationships (hierarchy and association), and runtime processes.
  - Documents the design and supports the design review process for TRAC-MTRY and TRAC-LEE.

- **Rapid Prototype (15 Mar 07): An implementation of the design with minimal functionality to prove out the top-level architecture.**

- **Stand-alone Model (11 May 07): The purpose of the stand-alone model is to provide an analysis capability separate from any combat model. (This is the initial capability, which is being refined and expanded.)**

LBC Near-Term Development

- **Test Harness: The purpose of the test harness is to act as a surrogate for a combat model to allow the interface between the combat model and the Logistics Battle Command module to be defined and proven. (30 May 07)**

- **Logistics Battle Command Module: The LBC module will implement additional features needed to interact with the combat model. (30 Jun 07)**

- **COMBAT Model Integration: The LBC module will be implemented with COMBAT XXI using placeholders for SBC functionality under development in COMBAT XXI . (30 Aug 07)**

- **Continued Model Development: Additional features and algorithms that were deferred from earlier phases will be added to the model as time and resources allow. Support for V&V. NPS thesis research and TRAC-LEE study support. (31 Jan 08)**

Future Research

- **Echelons Above Brigade (LBC4EAB).**
  - Funded Logistics FACT project.
  - Expand LBC to support analysis of forecasting and distribution at echelons above brigade.
  - Produce an enhanced stand-alone model capability with knowledge, data and algorithms that readily transfer to other models.
  - Emulate decision support systems capabilities like the Future COMBAT System (FCS) Logistics Decision Support System (LDSS) capability for forecasting consumption of supplies.

- **High Performance Computing and Design of Experiments.**
  - Objective is to design and develop services to allow constructive simulations to execute a statistical experimental design on a high performance computing cluster (HPCC).
  - Project will develop a design of experiments (DOE) tool, a data model and a data base implementation on an HPCC to support provisioning, execution and data services for various models.

The Team

- **LEE Analysts.**
  - Mike Byrd (SBC lead)
  - Mo Hayes (LBC stand-alone)
  - Robert Kaufman (CXXI Integration)
  - Erik Tollefson (dynamic sustainment)
- **FLVN Analyst.**
  - Curtis Bottom (AWARS)
- **MRO Analyst.**
  - Eric Johnson (OMS/MP)
  - Paul Works (C2)
- **MTRY Analysts.**
  - MAJ Rich Spainhour (distribution network)
  - Jack Jackson (battle command)
  - LTC Jeff Schamburg (forecasting)
  - CPT Bill Smith (logistics subject matter expert/research)

- **CASS Analyst.**
  - LTC Lawrence Fulton (medical)
- **R&A Contractors.**
  - Mr. John Ruck (lead developer, architect & CXXI integration)
  - Mr. Harold Yamauchi (distribution network & C2)
  - Mr. Jane Wu (dynamic sustainment & forecasting)
- **NPS Faculty and Students.**
  - LtCdr Roger Musselman (C2)
  - LtCdr Tony Costa (forecasting)
  - Capt. Ryan Heisinger (network modeling & optimization)
  - Professor Arnie Buss (architecture & modeling)
  - Professor John Alderson (optimization)
  - Professor Paul Sanchez (forecasting & HPCC/DOE)

Top Level Functional Requirements

- **General Requirements.**
  - **Related to the general functioning of the LBC model.**
- **Consumption of supplies.**
  - **The reduction in the quantity of supplies caused by usage.**
- **Distribution of Supplies.**
  - **The movement of supplies from one location to another whether implicitly or explicitly modeled.**
- **Demand for Supplies.**
  - **Demand is the determination that an entity requires a quantity of a type of supply.**
- **Battle Command.**
  - **The decision to initiate a logistics mission or action based on available information.**

Common Operational Picture

- **Current Status:**
  - **Current stock levels by location.**
  - **Orders in process.**
  - **Shipments in process including location.**

- **Plan:**
  - **Operational phases and tasks to units (e.g. execution matrix).**
  - **Logistics plan represented as a task network (PERT/CPM).**

- **Running Estimate:**
  - **Forecast of future consumption.**
  - **Identifies potential trigger points/decision points.**
  - **Estimates arrival of inbound supplies.**
  - **Characterizes the risks associated with the logistics plan.**

Logistics Distribution Network

- **LBC focus is on the supply distribution network.**
  - Arcs for ground (primary) plus sea, air & rail routes.
  - Nodes also support storage and transshipment.

- **Network provides a supply system in motion representation.**

- **Optimization simulates decision support (e.g. LDSS).**
  - Includes a very flexible cost function capability.
  - Provides mission planning and re-planning capability.

- **Expect to extract network data from combat model when integrated with COMBAT XXI.**

- **Developing a BCT use case based on current Army doctrine.**

- **MCCDC is interested in LBC for potential analysis of Sea basing and maritime pre-positioning.**

Logistics Forecast

- **Demand based on stock levels is the default if there is no forecast.**
- **Forecasted demand estimated based on projected stock levels:**
  - **Using past and current consumption rates.**
  - **Using projected consumption rates.**
  - **Using projected consumption profiles.**
- **Forecasted maintenance:**
  - **Failures.**
  - **Repairs.**
- **Forecasted distribution:**
  - **Delivery of supplies.**

Logistics Command & Control (C2)

- **Intent is to simulate C2 decision-making for Sustainment Battle Command.**

- **LBC focus is on prioritizing, planning, monitoring and adjusting sustainment missions.**

- **Potential Tools to emulate C2:**
  - **Bayesian Networks to recognize and act under uncertainty.**
  - **Task Network (PERT/CPM) for planning and monitoring.**
  - **Expert Systems to represent knowledge & assemble missions.**

- **C2 decision support:**
  - **Distribution network optimization for route planning and mission selection.**
  - **Forecasting to populate the running estimates.**

- **MTRY will leverage work at LEE to:**
  - **Capture the critical decision nodes, decisions, logic, and data/information required to emulate the sustainment decisions made by brigade and below-level commanders and staffs.**
  - **Develop metrics to measure the effects SBC has on the responsiveness of the supply and distribution systems.**
  - **Identify the critical nodes, decisions, and logic to take to the force-on-force models.**

Initial LBC Stand-alone Demonstration

- **Purpose: To show the initial analysis capabilities of the standalone implementation.**

- **A simple distribution system.**

- **Two supply items.**
  - **MREs.**
  - **Fuel.**

- **Constant periodic consumption.**
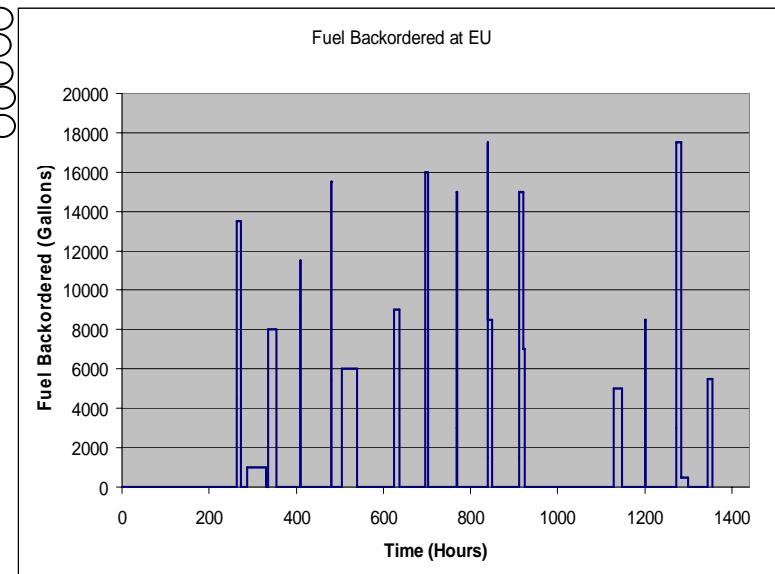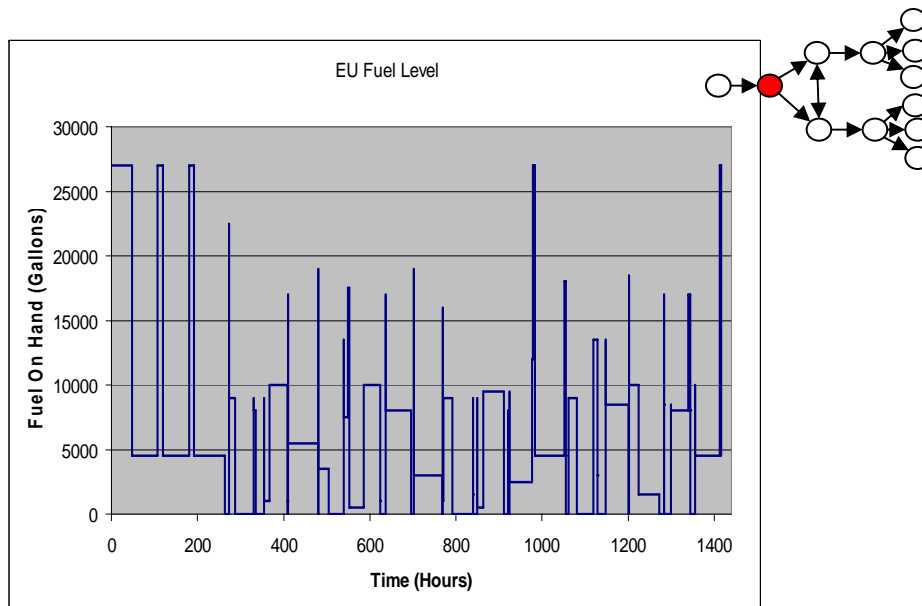 - **MREs at 500 units every 6 hours.**
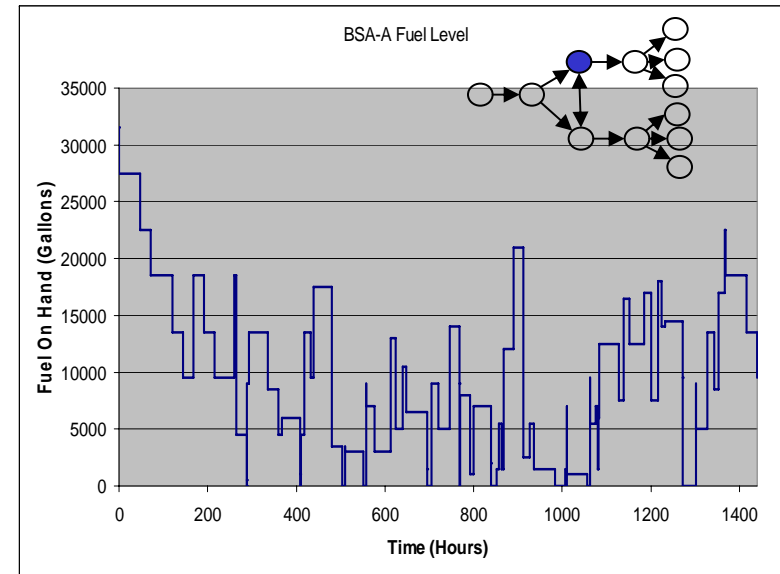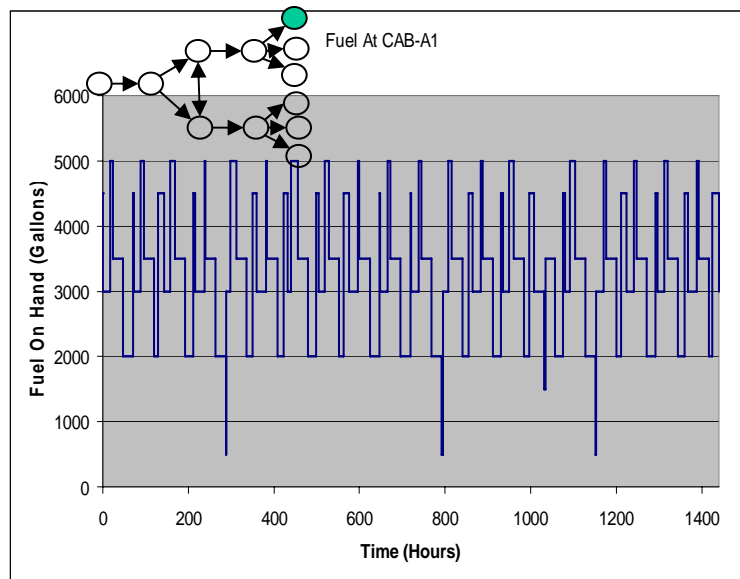 - **Fuel at 1500 units every 24 hours.**

Distribution System

- **CAB: Combined Arms Battalion**
- **FSB: Forward Support Battalion**
- **BSA: Brigade Support Area**
- **EU: Europe**
- **CONUS: Continental U.S.**

N(72.0, 7.2)

U(72, 168)

N(30.0, 3.0)

N(28.0, 2.8)

Triag(5.5, 16.0, 27.7)
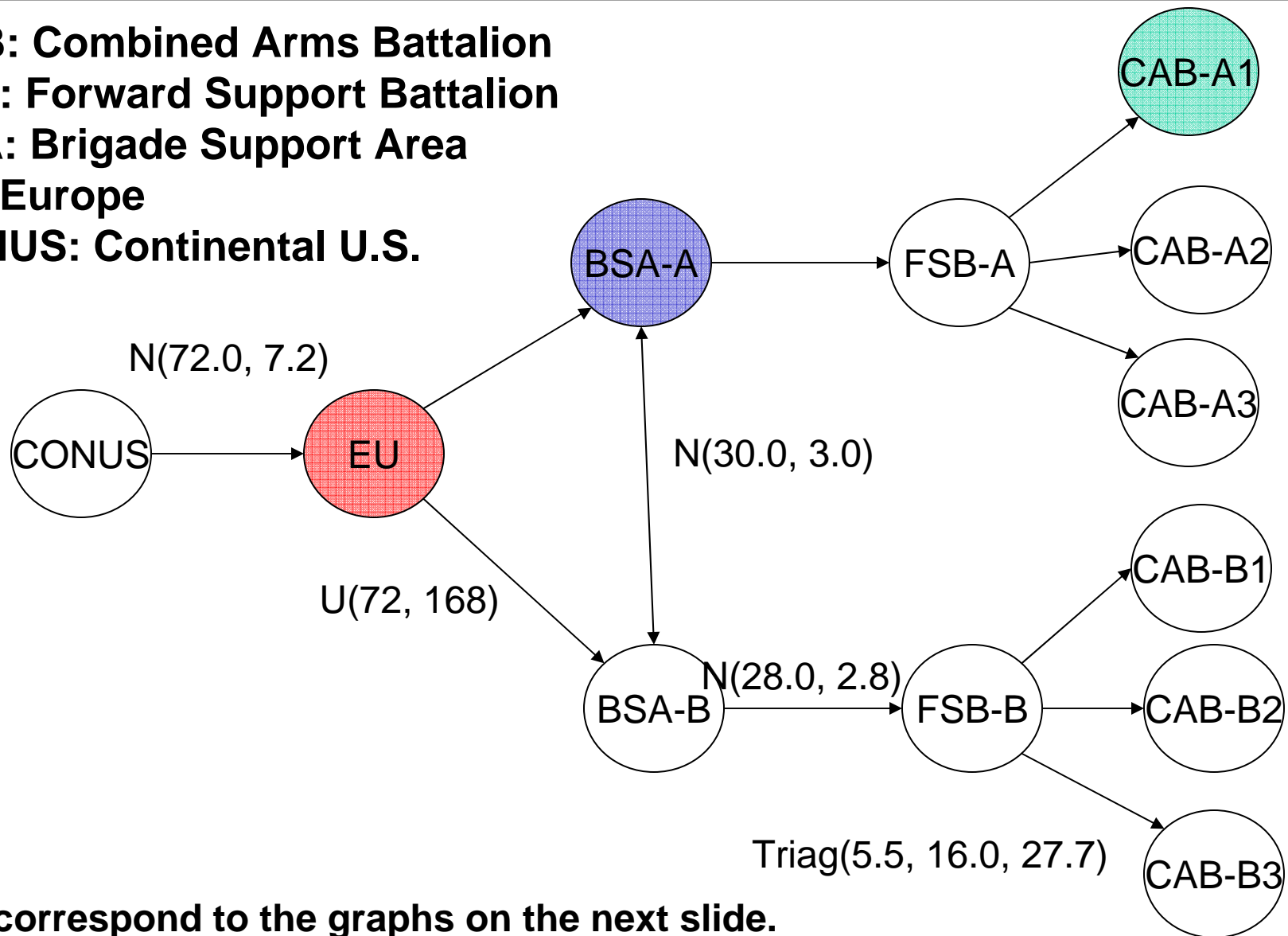
Colors correspond to the graphs on the next slide.

Example Output: Fuel

Demonstration of LBC With Dynamic Sustainment Generated Demands

- **Purpose: To show how new LBC functionality enhances the ability to analyze the cumulative effects of demand for parts.**
  - In DS, delivery times are currently modeled as independent stochastic events.
  - With LBC, the effects of past parts usage and the ability of re-supply are taken into account.

- **10 Different Repair Parts.**

- **2 System Types with failures.**

- **In the example graphs that follow, CAB's run out of high demand "Part0" causing ICV repairs to be deferred.**

Distribution System

- **CAB: Combined Arms Battalion**
- **FSB: Forward Support Battalion**
- **BSA: Brigade Support Area**
- **ISB: Intermediate Support Base**
- **EU: Europe**
- **CONUS: Continental U.S.**
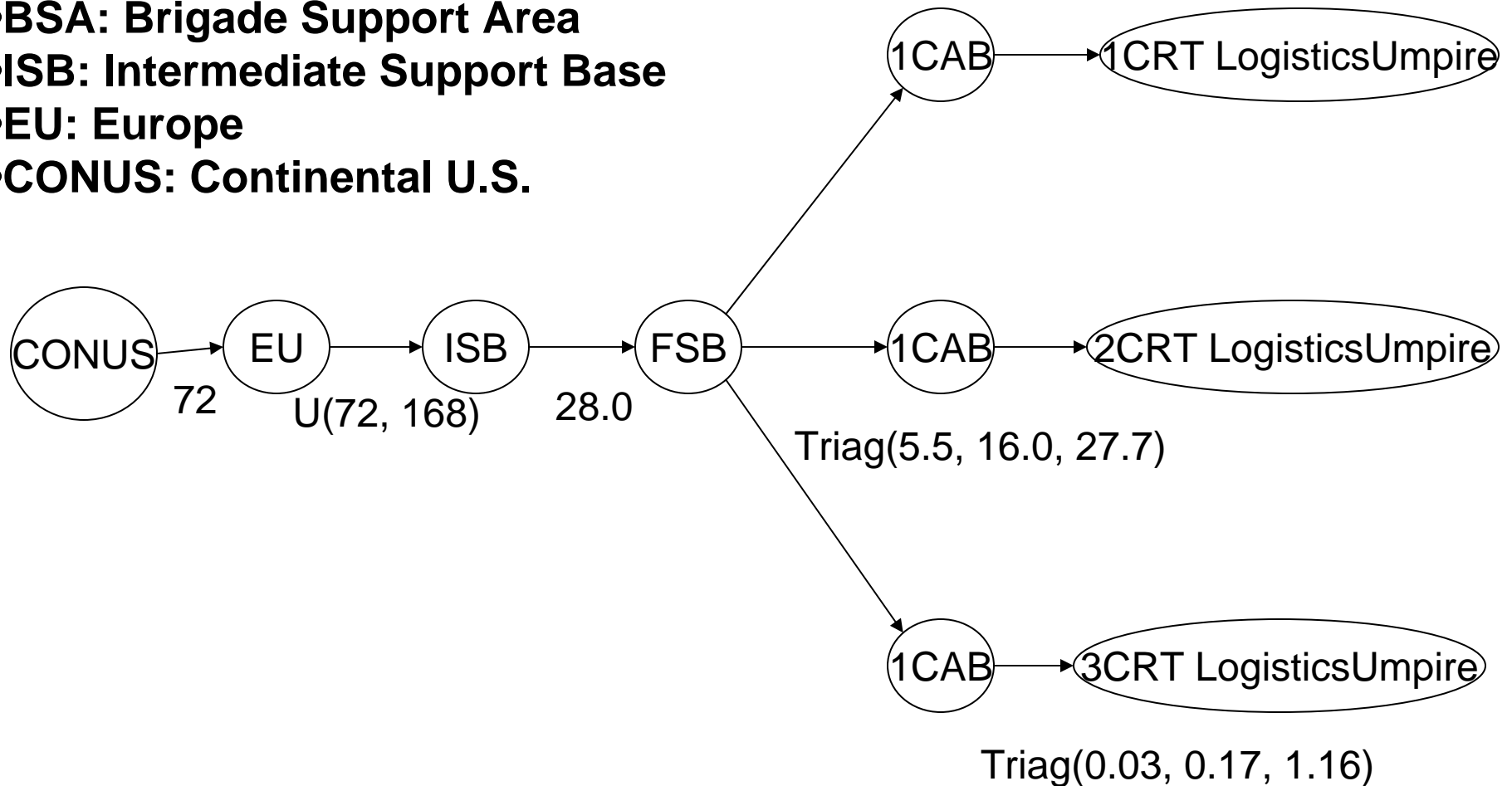
ICV Availability Example

1CAB ICV Available

Stock Level, Part0, 1CAB
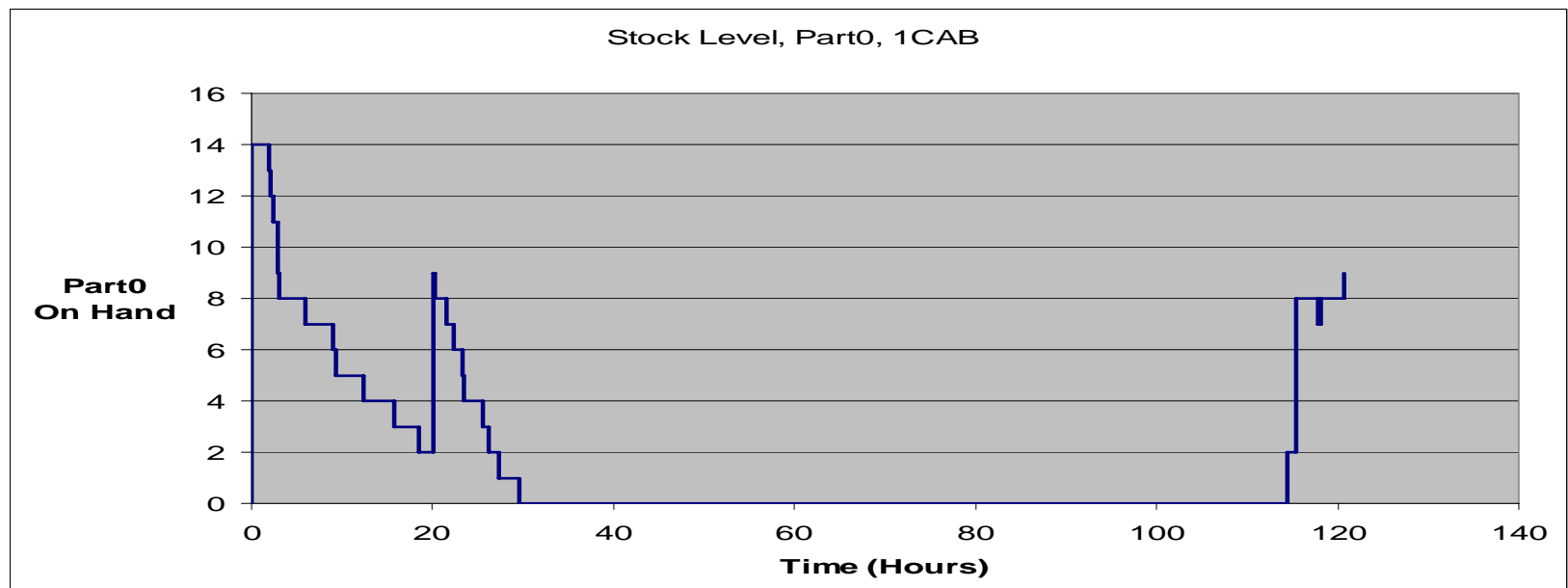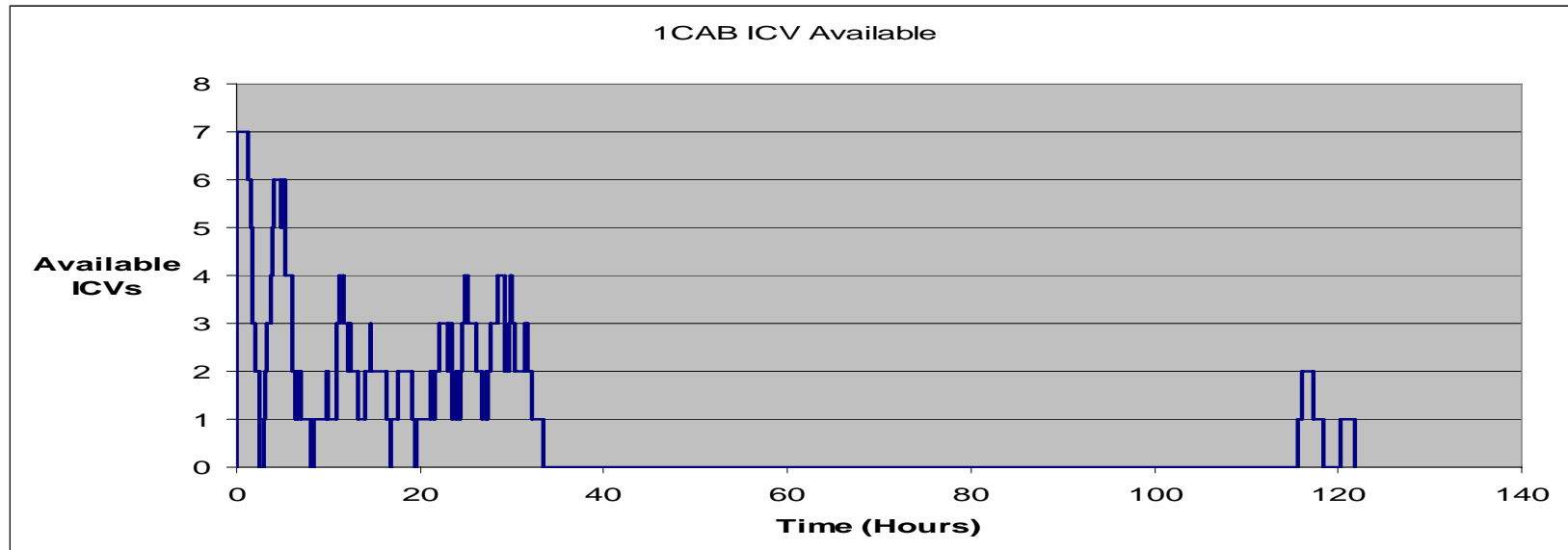
Dynamic Sustainment / Combat XXI Demonstration

- **Based on a Combat XXI Demo scenario that is included with the model.**

- **Will show:**
  - **Automotive failures generated by a "Mean Miles Between Failures" fault generator using OPTEMPO (miles traveled) data from CombatXXI . Causes tanks to stop when they fail.**
  - **Repair of the reliability failures.**
  - **Combat Damage generated by CombatXXI and repaired by Dynamic Sustainment.**
  - **Ability to log various data.**

COMBAT XXI Behavior

C:\cvsTemp\DynamicSustainment\tests\cxxiScenarios\Demo ScenarioModified.cxxi

- **TriggerPull**
- **InitializLogFM**
- **DamageOccurred**
- **GenericEvent**

Assigned to each entity that will be modeled in DS.
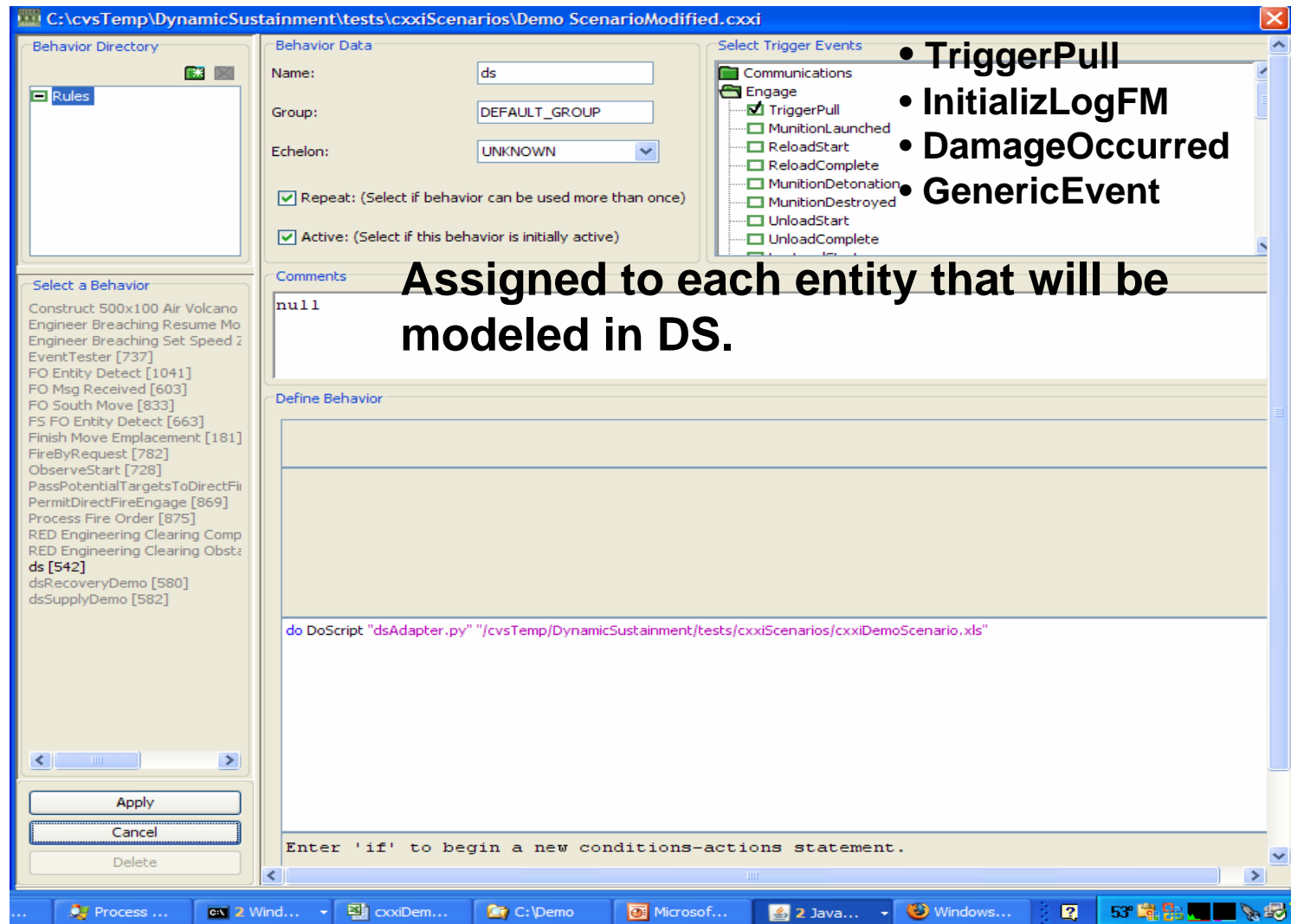
- **Dynamic Sustainment is triggered via a Combat-XXI behavior.**

Sample Combat XXI / Dynamic Sustainment Input Sheet

SystemType	Priority	RepairAsset	WorkRulesPeriod	WorkRulesLimit
M1A1	10	FALSE	-1	-1
M109A6	19	FALSE		
M1A1/PLOW	20	FALSE		
FDC	20	FALSE		
FO	21	FALSE		
F/A-16	22	FALSE		
UH-60A	23	FALSE		
M1025	5	TRUE	24	9

Used to define Dynamic Sustainment unique attributes of systems defined in Combat-XXI.
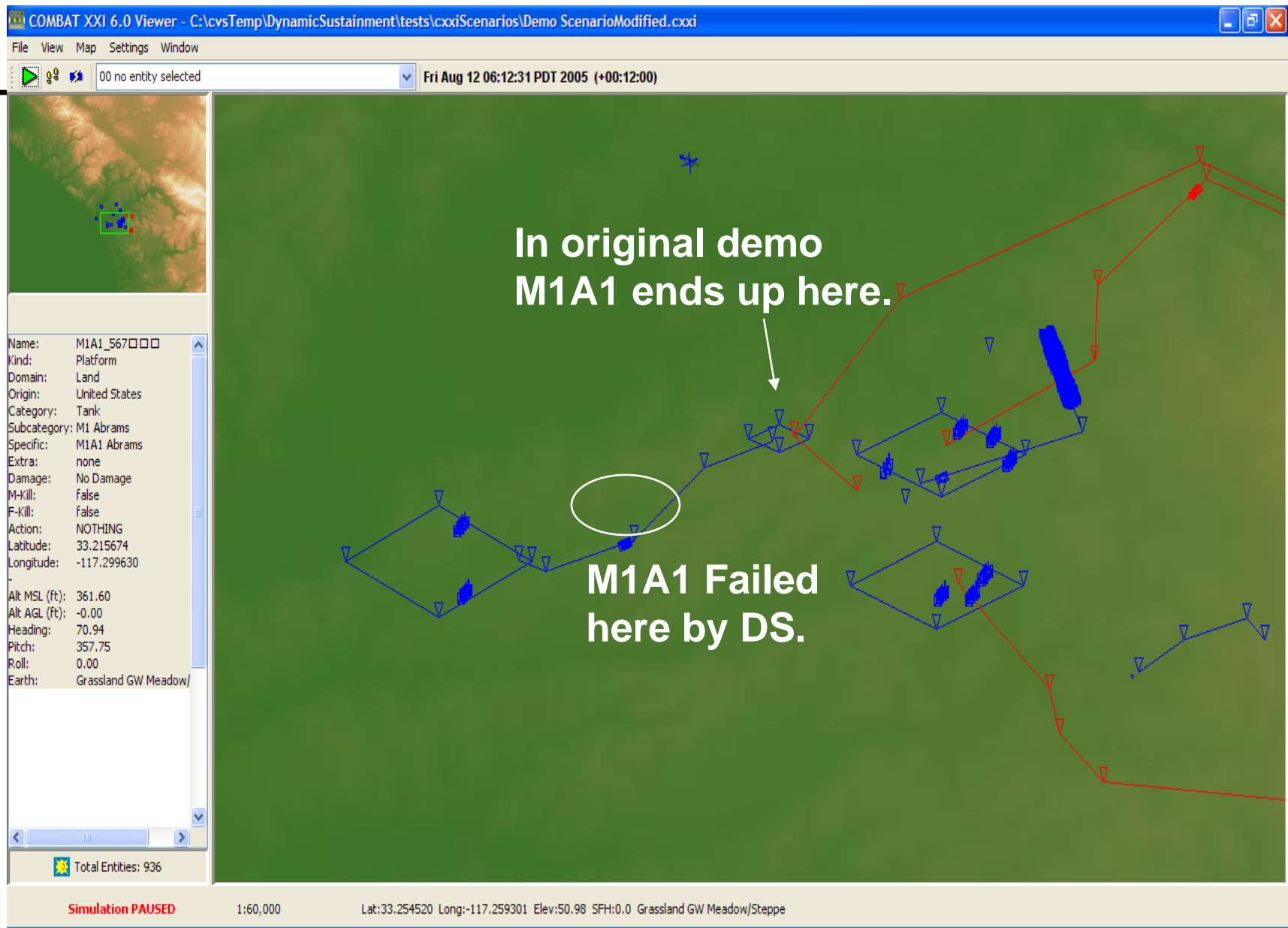
The Dynamic Sustainment Module provides a more realistic representation of reliability and availability of systems

Sample Failure/Damage/Repair Time Output

"Reliability Abort Data Logger Output"

| rep	time	CombatSystem	FailureMode	FailureModeStatus	Damaged	Failed
1	0.123135	M1A1_575	M1A1_575.EFF.Auto.61	failed	false	false
1	0.12318	M1A1_567	M1A1_567.EFF.Auto.217	failed	false	false
1	0.123242	M1A1_583	M1A1_583.EFF.Auto.205	failed	false	false
1	0.123998	M1A1_575	M1A1_575.SA.Auto.60	failed	false	true
1	0.124023	M1A1_592	M1A1_592.EFF.Auto.157	failed	false	false
1	0.124044	M1A1_567	M1A1_567.SA.Auto.216	failed	false	true
1	0.124105	M1A1_583	M1A1_583.SA.Auto.204	failed	false	true
1	0.124886	M1A1_592	M1A1_592.SA.Auto.156	failed	false	true
1	0.888107	M1A1_743	M1A1_743.EFF.Auto.109	damaged	false	false
1	0.888107	M1A1_743	M1A1_743.SA.Auto.108	damaged	true	false
1	0.888107	M1A1_743	M1A1_743.EFF.Arm.113	damaged	true	false
1	0.888107	M1A1_743	M1A1_743.SA.Arm.112	damaged	true	false
1	0.891048	M1A1_733	M1A1_733.EFF.Auto.139	damaged	false	false
1	0.891048	M1A1_733	M1A1_733.SA.Auto.138	damaged	true	false
1	1.077791	M1A1_583	M1A1_583.SA.Auto.204	repaired	false	false
1	1.517101	M1A1_567	M1A1_567.EFF.Auto.217	repaired	false	true
1	1.773777	M1A1_592	M1A1_592.EFF.Auto.157	repaired	false	true
1	1.924037	M1A1_743	M1A1_743.EFF.Arm.113	repaired	true	false
1	2.026226	M1A1_567	M1A1_567.SA.Auto.216	repaired	false	false
1	2.792525	M1A1_592	M1A1_592.SA.Auto.156	repaired	false	false
1	3.595684	M1A1_743	M1A1_743.SA.Arm.112	repaired	true	false

Miles Driven Failures

CXXI Generated Combat Damage

Failure Repair

Combat Damage Repair

Note: Time is in hours.

Example OPMODE Summary Type Data

M1A1_575 Speed
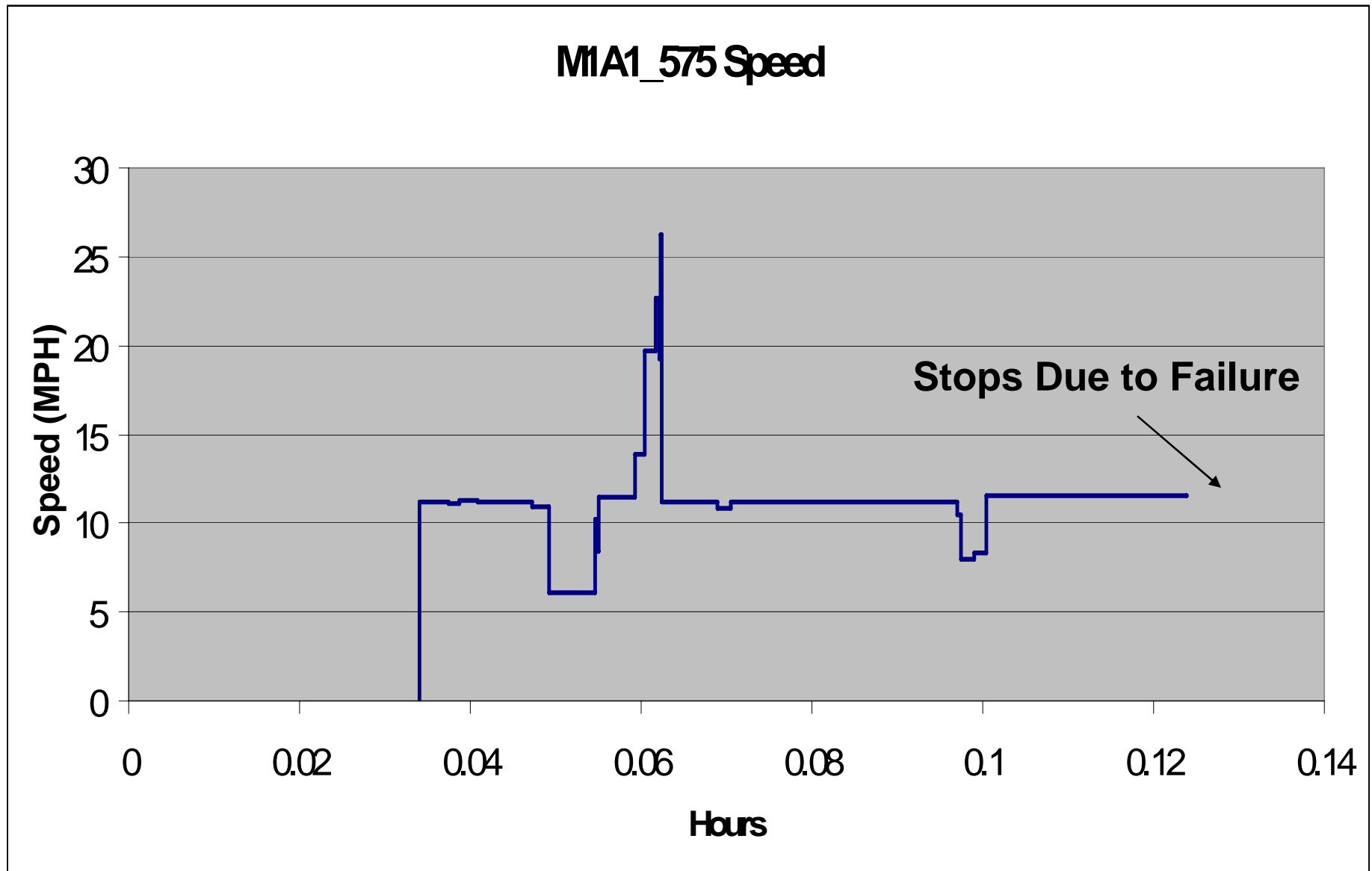
Maintenance Man Hour Sample Output

| replication	time	value	log	fai	fai	fai	fail	failu	requiredAssetType	repairCommander	propertyName	ok	low	hi	SD
1	2	0.184012	MM	AL	AL	AL	AL	ALL	M1025	1CRT RepairDepot	MMH Performed	1	Na	Na	Na
1	2	0	MM	AL	AL	AL	AL	ALL	M1025	1CRT RepairDepot	MMH Delayed	1	Na	Na	Na
1	2	0	MM	AL	AL	AL	AL	ALL	M1025	1CRT RepairDepot	MMH In progress	1	Na	Na	Na
1	2	0.184012	MM	AL	AL	AL	AL	ALL	M1025	1CRT RepairDepot	MMH Required	1	Na	Na	Na
1	3	0	MM	AL	AL	AL	AL	ALL	M1025	1CRT RepairDepot	MMH Performed	1	Na	Na	Na
1	3	0	MM	AL	AL	AL	AL	ALL	M1025	1CRT RepairDepot	MMH Delayed	1	Na	Na	Na
1	3	0	MM	AL	AL	AL	AL	ALL	M1025	1CRT RepairDepot	MMH In progress	1	Na	Na	Na
1	3	0	MM	AL	AL	AL	AL	ALL	M1025	1CRT RepairDepot	MMH Required	1	Na	Na	Na

Conclusions

- **Dynamic Sustainment was used in the Future Combat Systems FY07 OSD Review and was shown to be more efficient than the previous analysis process and also able to represent the maintenance system in greater detail.**

- **Logistics Battle Command further improves the representation of repair part delivery.**

- **Logistics Battle Command expands the Dynamic Sustainment capability to cover more classes of supply.**

- **Development and implementation of the forecasting and command and control models will improve the analysis of future sustainment.**

- **Logistics Battle Command will produce a tool that will make analysis of Future Combat Systems more effective and efficient.**

Questions & Discussion

Sample Output From 100 Replications
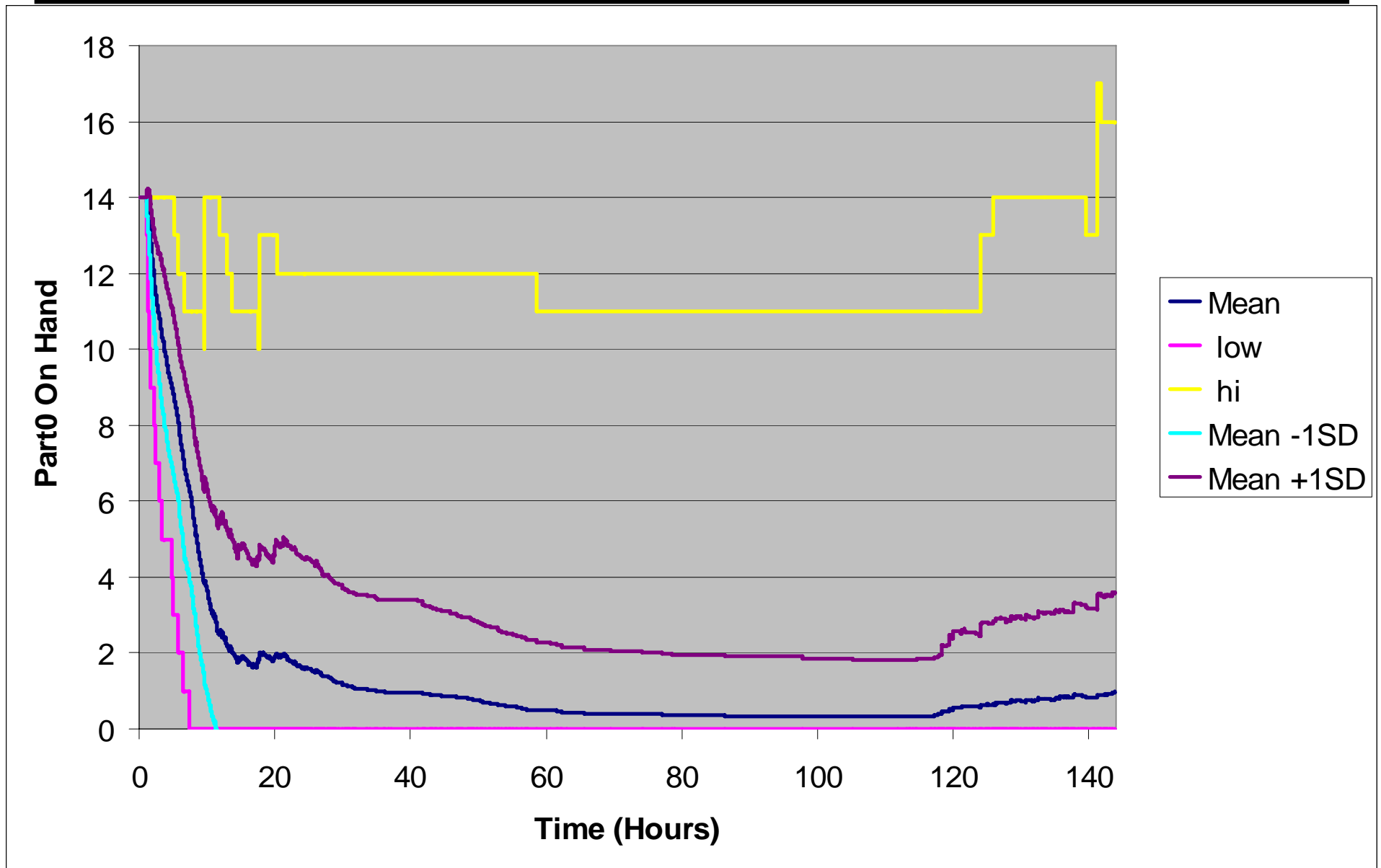
Sample Output for 10 Replications
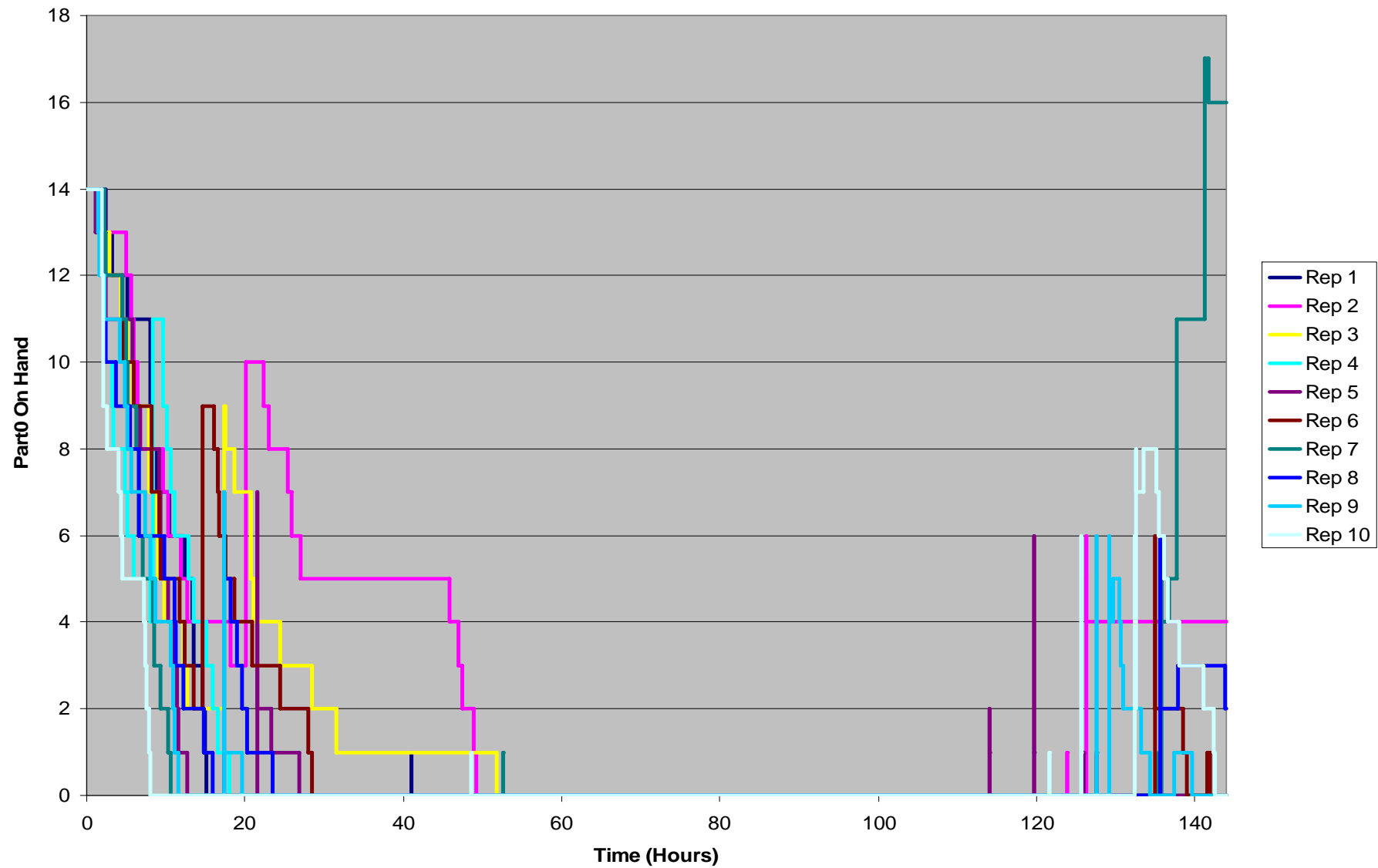
LBC Prototype Terminology

- **Consumption Logic: Decides when, what, and how much is consumed.**
  - PeriodicConsumptionLogic: A fixed amount periodically.

- **Consumer: Holds supplies, receives shipments and consumes supplies based on events scheduled by the ConsumptionLogic.**

- **Provider: Holds supplies and originates shipments.**

- **SimpleProvider: Both a Consumer and a Provider.**

- **LevelDemandCommander: Determines demand based on current stock levels, backorders, and orders in progress.**

Terminology (continued)

- **LogisticsC2: Decides which ProviderC2 to send requirements from the DemandCommander to be filled.**
  - **SimpleLogisticsC2: Uses a plan to determine how to fill a requirement. Based on consumable type, consumer, and order priority.**

- **ProviderC2: Decides from which Provider to fill an order.**
  - **SimpleProviderC2: Always uses the same Provider.**

- **TransportationUmpire: Routes a shipment from Provider to Consumer, determining if and when it gets there.**
  - **The explicit network will be an implementation of a TransportationUmpire.**
  - **RandomTransportationUmpire: Determines if and when a shipment arrives using random draws.**

"Full State" Output

replicati▼	time	value	loggerN▼	entityElement	entityName	propertyName	▼	▼	▼	▼	▼	D
1	0	NOT_FAILED_ACTIVE	State	FailureMode	M1A1_743.SA.Auto.108	state	CH	1	N	N	0	
1	0	NOT_FAILED_ACTIVE	State	FailureMode	M1A1_743.EFF.Auto.109	state	CH	1	N	N	0	
1	0	NOT_FAILED_ACTIVE	State	FailureMode	M1A1_743.SA.Comm.110	state	CH	1	N	N	0	
1	0	NOT_FAILED_ACTIVE	State	FailureMode	M1A1_743.EFF.Comm.111	state	CH	1	N	N	0	
1	0	NOT_FAILED_ACTIVE	State	FailureMode	M1A1_743.SA.Arm.112	state	CH	1	N	N	0	
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1	0.888107	FAILED_WAITING_TOW	State	FailureMode	M1A1_743.SA.Auto.108	state	CH	1	N	N	0	
1	0.888107	FAILED_WAITING_TOW	State	FailureMode	M1A1_743.EFF.Arm.113	state	CH	1	N	N	0	
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1	0.888107	FAILED_BEING_TOWED	State	FailureMode	M1A1_743.EFF.Auto.109	state	CH	1	N	N	0	
1	0.888107	FAILED_BEING_TOWED	State	FailureMode	M1A1_743.SA.Auto.108	state	CH	1	N	N	0	
1	0.888107	FAILED_BEING_TOWED	State	FailureMode	M1A1_743.EFF.Arm.113	state	CH	1	N	N	0	
1	0.888107	FAILED_BEING_TOWED	State	FailureMode	M1A1_743.SA.Arm.112	state	CH	1	N	N	0	
1	0.986852	FAILED_WAITING_PARTS	State	FailureMode	M1A1_743.SA.Arm.112	state	CH	1	N	N	0	
1	1.238255	FAILED_WAITING_PARTS	State	FailureMode	M1A1_743.EFF.Arm.113	state	CH	1	N	N	0	
1	1.832031	BEING_REPAIRED	State	FailureMode	M1A1_743.EFF.Arm.113	state	CH	1	N	N	0	
1	1.924037	NOT_FAILED_ACTIVE	State	FailureMode	M1A1_743.EFF.Arm.113	state	CH	1	N	N	0	
1	2.286592	FAILED_WAITING_PARTS	State	FailureMode	M1A1_743.SA.Auto.108	state	CH	1	N	N	0	
1	2.399273	FAILED_WAITING_PARTS	State	FailureMode	M1A1_743.EFF.Auto.109	state	CH	1	N	N	0	
1	3	FAILED_REPAIR_DEFERRED	State	FailureMode	M1A1_743.EFF.Auto.109	state	CH	1	N	N	0	
1	3.037172	BEING_REPAIRED	State	FailureMode	M1A1_743.SA.Arm.112	state	CH	1	N	N	0	
1	3.595684	NOT_FAILED_ACTIVE	State	FailureMode	M1A1_743.SA.Arm.112	state	CH	1	N	N	0	
1	3.595684	NOT_FAILED_ACTIVE	State	FailureMode	M1A1_743.SA.Comm.110	state	CH	1	N	N	0	
1	3.595684	NOT_FAILED_ACTIVE	State	FailureMode	M1A1_743.EFF.Comm.111	state	CH	1	N	N	0	